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AN INCREASE IN CONIFER SEEDLING SURVIVAL AND VIGOR ON AN EAST CASCADE SLOPE WITH A SOIL FUMIGANT

by

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ABSTRACT

In small experimental field plantings on the Wenatchee National Forest, the survival of Douglas-fir 2-0 seedlings increased from 45 to 91.9 percent after soil fumigation with methyl bromide. The vigor of both Douglas-fir and ponderosa pine seedlings also improved after fumigation. Biotic factor(s) may be restricting conifer seedling development on some east Cascade slope soils.

Keywords: Soil treatment(-natural regeneration, seedling survival.

Survival of newly planted conifer seedlings on the east slopes of the Cascades is frequently lower than desired. Many factors influence survival during the first year, including climate, availability of soil water and nutrients, rodent activity, competitive vegetation, and method of planting. In some areas where environmental factors and seedling quality appear favorable for survival, planting failures still occur.

Stewart and Beebe[1/] describe an example of low seedling survival in seemingly favorable circumstances in the Entiat Valley, Washington. Herbicides were being screened for use in reducing suspected plant competition with ponderosa pine (*Pinus ponderosa* Laws.) seedlings following erosion control seeding in a wildfire burn. Survival of ponderosa pine seedlings on a northerly aspect after 2 years without herbicide treatment on the residual soil was 3 percent. Where herbicides were used to control competing vegetation, the highest survival was 21 percent. Why did the rest die? They suggested that rodents could have accounted for up to 12 percent of the loss during the first winter but had no other explanation for the low survival. Soil physical properties (table 1) do not appear restrictive. Considerable mass soil movement in the area suggests high soil moisture levels during the early growing

Table 1.--*Soil physical properties, Entiat Valley, Washington*

Depth (cm)	Organic matter	Sand	Silt	Clay	Soil moisture	
					0.1 bar	15 bars
	- - - - Percent - - - - -				Percent (weight)	
15	1.45	35.4	54.5	10.1	36.2	6.5
30	.99	37.3	51.7	11.0	33.9	8.2
60	.63	35.7	53.3	11.0	26.3	6.5

season. Willow (*Salix* spp.) is one of the predominant shrubs, again suggesting that the site is mesic in character. Orchardgrass (*Dactylis glomerata*) planted in the area for erosion control was vigorous and suggests adequate plant nutrients for seedling survival.

One possible explanation for poor conifer seedling survival and growth is an unfavorable soil biotic condition. Soils of deciduous fruit orchards develop a condition sometimes known as "the replant problem, specific replant disease or bodenmiidigkeit."[2/] A simple rest for a few years does not seem adequate, but a preplant soil treatment with a general biocide alleviates the

[1/] R. E. Stewart and T. Beebe. Survival of ponderosa pine seedlings following control of competing grasses. Proceedings of the Western Society of Weed Science 27:55-58. 1974.

[2/] B. M. Savory. Specific replant diseases causing root necrosis and growth depression in perennial fruit and plantation crops. Research Review No. 1, Commonwealth Bureau of Horticulture and Plantation Crops, East Malling, Maidstone, Kent. 1966.

condition. The exact cause of this "disease" has not been determined. Benson *et al.*[3] have investigated poor growth of apple trees replanted in old apple orchard soils of central Washington. They have found a good survival and growth response to preplant soil treatment with chloropicrin or methyl bromide. Benson and Covey[4] also tested the survival and growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings in potted orchard soils in the greenhouse. Although statistical analyses showed no difference because of the high variability, seedlings in 4 of the 20 different orchard soils showed a 200-percent or greater growth increase as a consequence of soil fumigation with methyl bromide.

Comparing the observations of Benson *et al.* and the low seedling survival of Stewart and Beebe, we decided to test the possibility that some biological factor was involved. In 1974 we conducted our study adjacent to the residual soil plots used by Stewart and Beebe. Our objective was to determine the effect of soil fumigation with methyl bromide on ponderosa pine and Douglas-fir seedling survival.

METHODS

The study area was located near the 720-m elevation in the Mad River drainage of the Entiat Valley, north-central Washington. This area with a northern aspect receives about 46 to 60 cm of annual precipitation, mostly in the winter months. The local area was severely burned by wildfire in 1970 and had been selectively logged at some earlier date. Predominant prefire overstory vegetation was ponderosa pine and Douglas-fir. Understory was redstem ceanothus (*Ceanothus sanquineus*), willow, pinegrass (*Calamagrostis rubescens*), and lupine (*Lupinus laxiflorus*). The area received a postfire rehabilitation planting treatment; and the area is presently well vegetated with orchardgrass, pinegrass, redstem ceanothus, willow, and lupine.

A randomized experimental design was used in four blocks. Each block contained 10 replications. Treatment and nontreatment sites (plots) in each block were separated by 6 m. Two blocks were located on a lower slump bench and the other two blocks on another slump bench about 65 m higher in elevation.

On April 22, 1974, each plot was covered with a 1.2-m^2 sheet of black plastic. All sides of the plastic sheet were sealed with soil. On May 1 the designated plots were fumigated; 0.45 kg of methyl bromide with 2-percent chloropicrin was released at approximately the 60-cm depth beneath the plastic on the treated plots with a metal tube injector. All plots remained covered until May 20. On this date one ponderosa pine and one Douglas-fir were planted at each plot approximately 0.5 m apart. Seedlings used were 2-0 stock, with ponderosa pine from the U.S. Forest Service Nursery, Bend, Oregon, and the Douglas-fir from the U.S. Forest Service Wind River Nursery, Carson, Washington. These trees were part of the replanting stock from the appropriate seed source being used by the Entiat Ranger District on the same area. Total trees planted

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[3] N. R. Benson, R. P. Covey, Jr., and W. A. Haglund. Soil fumigation helps replants in old apple orchards. Proceedings of Sixty-Ninth Annual Meeting, Washington State Horticulture Association, Wenatchee, Wash. 1973.

[4] N. R. Benson, and R. P. Covey, Jr. Unpublished records on file, Washington State University, Tree Fruit Research Center, Wenatchee, Wash.

were 80 ponderosa pines and 80 Douglas-firs, with half of each planted on the fumigated plots. Soil moisture at planting time was 0.15 bar, approximately field capacity for this soil type.

Seedling survival, height, and vigor were measured on November 6, 1974, on all blocks. Vigor ratings on each seedling were scored as: 1--weak, 2--average, 3--good, and 4--excellent.

RESULTS AND DISCUSSION

Observations on July 5 and August 9 showed striking leader growth on the fumigated plots for both pine and fir. This growth response was not observed on the control trees. Three Douglas-fir trees were obviously killed by the residual fumigant. Soil moisture as measured by tensiometers on the lower plots at 15 cm next to the seedlings was 0.28 bar on July 5 and 0.55 bar on August 9. At 45 cm, it was 0.24 and 0.44 bar. During early September soil moisture exceeded 0.8 bar at both depths.

Survival of ponderosa pine on the untreated plots was 92.5 percent (table 2) and on the fumigated plots 97.5 percent, not significantly different ($p = 0.05$). However, the vigor rating for the fumigated plots was nearly twice

Table 2.--*Survival and vigor rating of ponderosa pine and Douglas-fir planted in untreated forest soil and soil fumigated with methyl bromide*

Treatment	Survival	Vigor rating[1/]
	Percent	
Ponderosa pine:		
Control	92.5	[2/]1.78
Fumigated	97.5	[2/]3.21
Douglas-fir:		
Control	[3/]45.0	[4/]1.94
Fumigated	[3/]91.9	[4/]2.91

[1/] 1 = weak, 2 = average, 3 = good, 4 = excellent.

[2/] Difference significant at 5-percent level.

[3/] Difference significant at 1-percent level.

[4/] Because of high variability due to poor survival of control, this value is statistically non-significant.

that of the untreated plots, 3.21 compared with 1.78, which was statistically significant at the 5-percent level.

Douglas-fir seedling survival on the untreated plots was 45 percent and on the fumigated plots 91.9 percent, a highly significant difference ($p = 0.01$). The Douglas-fir vigor rating for the untreated plots was 1.94, compared with

2.91 for the fumigated plots. This difference was not significant at the 5-percent level--most likely due to the influence of high mortality on the untreated Douglas-fir.

Over all plantings, ponderosa pine had the highest survival in the upper two blocks (100 percent versus 90 percent) and Douglas-fir the lowest (59 percent versus 77.5 percent). Height was not measured at planting time, so first-year total growth is unknown.

It appears that we have modified some soil biotic factor(s) which may be restricting seedling development such as the presence of some organism(s) that becomes directly pathogenic to the newly transplanted conifer seedling. Other possibilities include a severe reduction in resident organisms that could release nutrients that otherwise would be biologically bound, although this could hardly account for poor seedling survival. Microbial population reduction and, especially, altering the population composition could reduce competition and antagonism against the mycorrhizal fungi on the roots of the planting stock. This could easily account for the lower vigor on the control trees and could also account for poor survival if some nutrient, for example, zinc or copper, were severely limiting. To account for this difference in behavior of the Douglas-fir and ponderosa pine, we must suggest that the pine was more tolerant to the factor(s) controlled. If moisture stress occurred, then this biotic factor could be involved in the survival differences of the two species because of the physiological nature of water use by the Douglas-fir,[5/] but stress did not appear to occur until late summer. By this time, some fir seedlings already appeared to have died. The observation of increased vigor following fumigation in the presence of adequate moisture is similar to the response noted in deciduous fruit trees where soil moisture stress is not allowed to develop. Poor survival of transplanted fruit trees has also been noted but has been attributed to arsenic. However, poor survival does not occur following fumigation.

We are not presently suggesting the use of methyl bromide or any other chemical or biotic treatment to enhance seedling survival and growth. We have shown that seedlings did not perform according to their potential on our experimental site and the cause may be biologic in nature. Further studies on the reason for the positive response to fumigation would appear to be warranted. Such studies could provide recommendations for planting forest sites with a history of low replant survival.

[5/] W. Lopushinsky and G. O. Klock. Transpiration of conifer seedlings in relation to soil water potential. Forest Science 20(2): 181-186. 1974.

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